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Introduction

The keeping of ornamental fish may be the most popular animal-oriented hobby in the United States. One household in every three owns and cares for some type of pet fish. In 1985, approximately $200 million was spent on aquarium fish retail sales. An additional $289 million was spent on aquarium supplies and another $93 million in fish food.[1] Although some varieties may be purchases at low prices, people rarely own one fish and the aggregate value of fish in the home aquarium can become quite large. The loss of individual fish may not be expensive, but numerous losses of inexpensive fish can be costly. The growing number of fish hobbyists have few "experts" to turn to when aquarium problems arise. Many fish hobbyists have other pets in their households requiring veterinary care, therefore they will frequently ask for veterinary advice for their fish health problems.

Evaluating Fish Health Problems

The basic principles of epizootiology, host-parasite relationships, and environmental control are as applicable to fish as other animals. A basic understanding of aquatic husbandry techniques and fish physiology can go a long way for veterinarians with clients who are aquarists.

Approaching problems in the aquarium involves the same basic diagnostic principles used for any animal health problem. Changes in behavior frequently offer clues that direct the evaluation of a problem. Fish tend to show more immediate reactions to environmental changes than do terrestrial species because of the intimacy which exists between fish and their environment. Veterinarians must keep in mind that there are two environmental factors dominating the fish's existence: the quality of the aquatic environment, and the moderating effect of temperature on the metabolic processes of poikilotherms, especially their defense mechanisms.[2]

If it is necessary to see the patient, clients should be instructed on what to bring. For problems involving a full tank of fish, the most ill but live specimen should be brought to the clinic. Recent mortalities may be brought as well, but in a different container. The live fish should be transported in enough water to allow it to swim upright and turn around. A container of an equal amount of water from the involved tank should be brought in a separate container. This water may be useful for testing, but more importantly, the water can serve as recovery water should the patient need to be anesthetized. If the weather is extremely hot or cold, the contained fish should be insulated.

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Assessing Water Quality

The major cause of fish disease and mortality is poor water quality. Water quality is probably the most complicated part of aquarium management and the most important. It is necessary to have an understanding of water quality principles in order to successfully diagnose and correct aquarium problems.

Oxygen

Oxygen is the most important life supporting component found in water. Water contains much less oxygen than air (0.004% in sea water and 21% in atmospheric air).[3] Most fish need to ventilate a volume of water ten times that of the air ventilated by a land animal to obtain the same amount of oxygen. The amount of oxygen dissolved in a given amount of water is dependent upon four factors: temperature, atmospheric pressure, salinity, and aquatic plant life.[3,4] In water, oxygen is either saturated, supersaturated, or undersaturated. With an adequate aerator most household aquariums are saturated and contain plenty of oxygen for the resident fish. Supersaturated water can lead to a disease problem known commonly as "gas bubble disease," which occurs when atmospheric gases actually come out of solution in the bloodstream of fish. The resulting emboli can kill the fish. This problem can also present itself as subcutaneous air bubbles on the affected fish.

pH

pH in itself is not nearly as important as how it is related to other water chemistry parameters such as ammonia. Ammonia below pH 7 is unlikely to be a problem. Unionized ammonia (NH_3) is highly toxic to fish and builds up in alkaline waters. The normal pH range for freshwater fish is 6.8 to 7.8.

Carbon Dioxide

Quite a lot of CO_2 is found in natural water. After it enters water, a small percentage is hydrated into carbonic acid. Some of this carbonic acid dissociates into carbonate and bicarbonate ions which are the primary buffers found in fresh water. Aquatic plants utilize CO_2 for photosynthesis. In the marine environment, CO_2 can precipitate as calcium carbonate and become incorporated into the shells and exoskeletons of marine invertebrates.

Many aquariums tend to be eutrophic (high in plant nutrients) and therefore unbalanced since CO_2 production exceeds reduction and precipitation. This results in poor buffering capacity and an acid environment. Tanks which contain many aquatic plants may require addition of a buffer such as calcium carbonate.

Nitrogen

Most of the nitrogen entering a tank comes in the form of ammonia which is excreted by fish directly into the water. Nitrogen cycling in most aquaria is performed by two genera of nitrifying bacteria . These bacteria and the substrate they adhere to is termed the biological filter or biofilter. The nitrogen compounds which are dissolved in aquarium water are ammonia, nitrite, and nitrate.

Ammonia

Ammonia in water occurs in two forms: toxic unionized ammonia (NH_3), and the relatively non-toxic ionized form (NH_4^+). The actual proportion of each compound depends on temperature, pressure, salinity, and pH. Generally, the higher the pH, the more unionized ammonia present. A good rule to follow is any unionized ammonia reading greater than .025 ppm should be considered dangerous over long periods.[3] Salt water fish tend to be more sensitive to NH_3 than freshwater fish.

Nitrite

Nitrite is an intermediate compound in the nitrogen cycle and is converted to nitrate by a healthy biofilter. Problems usually arise when nitrite levels rise above 1.0 ppm, but levels as low as 0.1 ppm may also affect fish adversely. Nitrite results in the formation of methemoglobin in the blood and results in respiratory compromise. Affected fish display signs of oxygen deprivation and may die of asphyxiation.

Nitrate

Nitrate is the last compound in the nitrogen cycle and is non-toxic to fish. High levels may result in excessive algae growth. Regular water changes will help control nitrate levels if problems arise.

Alkalinity and Hardness

Alkalinity can be defined as equivalent calcium carbonate and expresses buffering capacity. This holds true for fresh as well as salt water, but in the marine environment, about 5% of the total alkalinity is due to borate ($H_2BO_4^-$). This buffering capacity is primarily dependent on the anions (bicarbonate and carbonate) and not on the cations (calcium and magnesium).

Hardness represents the total concentration of all cations in fresh water and is usually expressed in mg/L calcium carbonate. Calcium and magnesium are the major cations associated with the carbonates. Soft water (0-60 mg/L) generally has poor buffering capacity while hard water (>180 mg/L) generally has good buffering capacity. Alkalinity measures buffering capacity while hardness measures dissolved cations, which is usually an accurate but indirect measurement of buffering capacity.

Salinity and Chlorinity

"Sea salt" contains traces of many elements, but six elements comprise over 99% of the sea salt.[3] These six elements are chlorine, magnesium, sodium, calcium, potassium, and sulfur. Ocean water tends to be well mixed and rather stable in terms of salinity and elemental concentrations. Chlorinity is the amount of chloride ion (plus bromine and iodine) dissolved in one kilogram of sea water.

Introduced Toxic Compounds

Sources of tank water should be included when evaluating tank problems. The addition of chlorine to municipal water supplies is a common sterilization method used in drinking water. While harmless to humans, chlorine can be deadly to tropical fish. Removal of chlorine can be done with an aerator ("bubbled" out) or by simply letting the water stand over a period of several days. Chlorine can be removed instantly by the addition of commercially available compounds. These compounds employ sodium thiosulfate which inactivates the chlorine through a chemical reaction involving NaCl formation.[3]

Another compound used in municipal water supplies is chloramine, which combines chlorine with ammonia, both harmful to fish health. Bubbling the water or letting it stand will not remove chloramine. The water needs to be treated with a dechlorinator like sodium thiosulfate.

Copper sulfate may occasionally be added to municipal water to help control algal growth. Levels over 0.15 ppm are dangerous to freshwater fish and levels over 0.2 ppm can be harmful to marine fish. Copper test kits are readily available in aquarium stores. High copper concentrations require a special type of filter for removal since there is no acceptable way to remove copper from water without doing water changes with clean, uncontaminated water.[3]

Filtration

A filter removes harmful components from the water. Successful aquarium systems will have at least one type of filter and many of the better tank systems are equipped with two or more types of filters. There are three major types of filters: biological, mechanical and chemical.

Biological

Biofilters are the best and most efficient means of removing ammonia. The natural process of nitrification is utilized in biological filters in a two step process involving bacteria. *Nitrosomonas* oxidizes ammonia to nitrate and *Nitrobacter* oxidizes nitrite to nitrate. It takes several weeks for a healthy filter to develop and begin functioning adequately. Loading a tank with fish before the filter is established will result in "New Tank Syndrome".[5] Starting a tank with a few hardy fish and then gradually adding more fish over time will prevent this problem.

Mechanical

Mechanical filters essentially strains particulates from the water. These filters will usually not remove particles smaller than three microns, such as ammonia ions. Out-of- tank power filters, sand filters, diatom filters, and in-tank box filters all employ mechanical filtration. Most good aquarium systems combine biological and mechanical filtration.

Chemical

Activated charcoal is the primary means of chemical filtration. Activated charcoal binds organic compounds efficiently and acts as a substitute for a biological filter. It is commonly combined with mechanical filtration and enables the system to remove ammonia and other organic compounds that mechanical filters alone cannot remove.

Temperature Control

Temperature is the easiest parameter to control, yet it is most commonly overlooked by the beginning aquarist. Most tropical fish require consistently warm water. Freshwater fish do best between 75° and 80° F, while marine fish prefer slightly warmer temperatures. A good temperature range to shoot for is 77° to 78° F.

Tank Loading

The number of fish that can be put in a tank varies with the size of the tank and the filtration system employed. General guidelines are as follows: three inches of fish per gallon in fresh water and one inch of fish per three gallons of water in marine tanks.[3]

Diagnostic Techniques

Diagnostic procedures in fish should be carried out rapidly. Fish should be handled while wearing latex gloves to prevent damage to the protective mucus layer. Most diagnostic tests require that the fish be anesthetized to prevent stress and injury. Cytologic examination of scrapings and biopsies taken from external surfaces and gills of fish are the simplest and most valuable diagnostic procedures. Hematologic evaluation and bacterial and fungal cultures can also be useful diagnostic tools in fish medicine.

Clinical cytologic examinations can be performed on a wide variety of specimens obtained from fish. A variety of cytologic stains are available and can be used for fish samples without modification. Wright's, Giemsa, new methylene blue, hematoxylin-eosin, phenol cotton blue, Gram stain, acid-fast stain, and modified quick Wright's stain are useful. Rapid stains (Diff-Quik and Hemacolor) also provide good staining quality.[6]

Skin and Gill Scrapings and Biopsies

Fish frequently suffer from disease conditions with lesions involving the integument. A common response of the skin is hyperactivity of epithelium and goblet cells. This results in a thickening of the epithelium or increased mucus production that can give a cloudy appearance to the skin. Since the epidermis is not vascularized, there can be extensive epidermal damage without bleeding.[6]

Most teleost fish are covered by scales. The skin is composed of noncornified, stratified squamous epithelium. Cytologic specimens often reveal a variable number of squamous epithelial cells and debris from scales with occasional goblet cells. Ulcerative lesions involving the skin often expose the underlying dermis and spindle-shaped fibroblasts may be seen.[6] Cytologic examination of a lesion also provides the opportunity to observe parasitic organisms directly.

Skin scrapings in fish should be performed on anesthetized fish. The edge of a beveled glass coverslip or edge of a slide is used to gently scrape the surface of the fish in the direction of its scales, avoiding removal of a large number of scales or injury to the fish. A wet-mount preparation is prepared by placing a drop of aquarium water on the cover slip and mounting on a glass slide.[7] Wet-mount impression smears can be made by placing a coverslip directly on the lesion. Small fin biopsies can be taken using iris scissors and making a wet-mount squash preparation between a coverslip and slide.

Gill biopsies can be taken by lifting the operculum and excising a small portion of the free border of the gill row. A wet-mount squash preparation can be made, or the biopsy can be placed in 10% buffered formalin for histologic examination. The wet-mounts should be examined immediately, as protozoan parasites die quickly and are much easier to identify while alive.[7]

Hematologic Examination

The routine tests used in hematology include erythrocyte, leukocyte and thrombocyte evaluation. In general, the PCV of fish is lower than that of mammals and birds. The baseline values may be less than 20% for some species. fish with values greater than 45% are usually considered hemoconcentrated. Stained blood smears can be used to identify hemoparasitism, estimate WBC counts and to study RBC and WBC morphology.

A plastic syringe is recommended for blood collection because fish blood coagulates rapidly when in contact with a glass surface. Heparin and EDTA are both suitable for coating the syringe and needle to serve as an anticoagulant.[6] Fish should be anesthetized for blood collection procedures. The preferred venipuncture site is the caudal vein lying ventral to the base of the tail. The vein can be approached by inserting a needle on the ventral midline of the tail down to the vertebrae or laterally a few scales below the lateral line and directed just caudal to the vertebrae.[7]

In small fish, blood sampling is often a sacrificial procedure. After anesthetizing the fish, the body cavity is opened. A needle is inserted in to the exposed heart and blood is aspirated. An alternative method, with the disadvantage of increasing the contamination of the sample, is to sever the caudal peduncle while holding the fish tail over a microhematocrit tube. In fish too small to be bled by conventional means, lamellar biopsy of the gill can be used.[6]

Diseases of Fish

In most cases, veterinarians face the dilemma of suggesting a treatment without having first made a definitive diagnosis. In light of this, familiarity with the disease problems most frequently affecting fish can be useful. For prevention of many diseases, a quarantine period of three weeks in an aquarium with a biologically activated filter is recommended before adding fish to an established aquarium.[5]

Bacterial Diseases

One of the principal causes of aquarium fish mortality is bacterial disease. Most of the bacteria affecting fish are gram-negative aerobes or facultative anaerobes. Potentially pathogenic bacteria are present in the fish's environment as well as in and on the fish itself. The total number of bacteria per mL of aquarium water can be between 10^4 and 10^6 organisms.[6] Bacterial blooms which are noted as cloudy water require approximately 10^7 organisms per mL. Such blooms can be associated with overfeeding.

The presence of bacteria on the fish or in the water is never equated with disease or imminent potential disease.[5] Fish succumb to bacterial infections after they have been exposed to a stress such as parasitic infections, poor nutrition, poor water quality, shipping, and temperature extremes. Bacterial pathogens commonly found in tropical fish are *Aeromonas hydrophilia* complex, *Flexibacter* spp., *Vibrio* spp., *Streptococcus* spp., and *Mycobacterrium ss*p.

Bacteria can be transmitted orally and through skin abrasions or damaged gills. Clinical signs of bacterial infections are similar. Diagnosis of most bacterial infections is based on culture and isolation of the causative organisms in a lesion. Mycobacterial infections are diagnosed by microscopic examination of acid-fast organisms in tissue smears.[6] Mycobacterial infections have zoonotic potential and may result in "aquarium finger" or "tropical fish finger" in humans.

Fungal Infections

Generally considered opportunistic pathogens, fungi are frequently secondary invaders of wounds and often colonize dead fish. They invariably follow injuries, parasitic infestations or bacterial infections.[2] Water molds are ubiquitous and can commonly be isolated from water and sediments.[6]

Saprolegnia and related genera are the most common fungi affecting freshwater fish. They do not affect marine fish. They are typically superficial, cottony growths on the skin and gills that grow in a radially symmetrical pattern. The mycelia trap debris so that the lesions may eventually lose their white coloration. The presence of broad aseptate hyphae are diagnostic. Since all fungal infections are treated similarly, further identification is not necessary.[6]

Ichthyophonus hoferi is an obligate internal fungal parasite that primarily affects marine fish. Ingestion of infected viscera from feed prepared from infected fish or infected tankmates is probably an important means of transmission. A granulomatous disease is produced which is clinically similar to mycobacteriosis. Squash preparations of infected lesions reveal the thick-walled "resting spores" which are variable in size up to 200 micrometers in diameter.

Parasitic Infections

Many species of ectoparasites and endoparasites can infect fish and may cause high mortality rates. Fish may have protozoan, metazoan, and crustacean parasites, which are readily identified microscopically. Fish may carry a parasite or a population of a few classes of parasites without apparent signs of disease. Many carriers are mature fish that may have developed a degree of immunity to a particular parasite.[6] When introduced into a group of uninfected fish, the carrier will initiate an epidemic within the aquarium without showing any signs of disease themselves.

Many parasites affecting fish can be transmitted by direct extension through the water. Live foods can introduce disease-producing organisms to the tank. Many fish parasites require an intermediate host which may be present in the aquarium. Environmental factors can enhance the clinical severity of parasitism, including crowding, water quality changes, and nutrition.

Viral and Neoplastic Diseases

Lymphocystis disease is caused by a DNA-containing iridovirus. The virus infects dermal fibroblasts and induces them to undergo extreme hypertrophy.[7] Infection results in proliferative nodular growths on the skin that vary in size from pinhead-size nodules to extensive proliferative masses covering large portions of the body.[6] The disease may be self limiting,[3] or fish may die of generalized, diffuse skin involvement. There is no treatment for lymphocystis disease. Surgical removal of lesions may be beneficial. In the wild, fish are thought to spontaneously recover from the disease. Lymphocystis is more likely to develop if fish are stressed.

Compared to infectious diseases, neoplasia is uncommon in fish. Tumors of various origins have been documented.[6] Fish tumors rarely metastasize. Damage is typically due to local injury from tissue invasion or pressure necrosis. Ulcerated lesions may become secondarily infected. Treatment for neoplasia in fish is excision.

Anesthesia in Fish

Fish should be anesthetized during any procedure that is stressful or likely to cause pain. The majority of anesthetics are administered in water through the gills. They may also be given intramuscularly, intraperitoneally, and orally. A general requirement for all methods of anesthesia is withholding food for 24 hours to prevent complications of regurgitation.[6]

The most common method of anesthetic administration is direct immersion of the fish. The fish is placed in an aerated container of water from its own aquarium with the anesthetic in solution and monitored for changes in swimming behavior. The fish may be removed when the desired depth of anesthesia is obtained. Recovery is accomplished by placing the fish in a second aerated container of fresh water from its own aquarium.

Anesthetic Agents

Tricaine Methanesulfonate (MS-222, Finquel)

MS-222 is the only anesthetic agent licensed for use in food fish by the FDA. Dosages required to produce sedation in fish vary from species to species. As a general guide, sedation occurs at 20 to 50 mg/L, and surgical anesthesia at 50 to 100 mg/L, to effect. Induction occurs within three minutes. Most fish will recover uneventfully in 10 to 15 minutes after being placed in clean, fresh water. MS-222 also works on amphibians.[3]

Benzocaine

Benzocaine is not soluble in water. A stock solution using 10 grams benzocaine in 250 mL of acetone gives a concentration of 50 mg/L, and can then be diluted in water to the desired concentration. It can be administered as a bath or in a recirculation system. Sedation is obtained using 15 to 30 mg/L.[6]

Alka-Seltzer

An Alka-Seltzer tablet dissolved in a small amount of water is an effective but stressful anesthetic.[8] Its use is not recommended.

Euthanasia in Fish

Euthanasia in fish is typically through overdose of an anesthetic agent. MS-222 at a concentration of 150 to 500 mg/L will humanely kill most species of fish.[3,6] Large fish can be lifted out of the water and administered concentrated anesthetic solution by using a syringe to pour the solution directly onto the gills. Other methods that have been used include decapitation and intraperitoneal administration of pentobarbitone or other anesthetic.[6]

Fish Chemotherapeutics

Drugs can be administered to fish orally (PO), intramuscularly (IM), intraperitoneally (IP), intravenously (IV), or topically in baths or dips. Topical administration is the most commonly used method. Dosages are based on aquarium volume rather than fish biomass. To calculate the volume of an aquarium, multiply the depth of the water by the width and length of the aquarium in inches and divide by 231.[5] This will give volume in gallons. There are three basic forms of topical administration of drugs: localized topical administration, short and long-duration baths and dips, and tank treatments.

Tank treatments

Probably the most frequently used method of treating small fish, with the major advantage being ease of administration. However, achieving safe but therapeutic levels of most drugs is difficult. Drugs tend to bind substrates and organic debris in the tank. Biofilters, plants, and invertebrate inhabitants can be severely affected by some drugs.

Long and short duration baths and dips

These treatments require handling the fish but have the advantage of sparing the environment. A separate container is filled with a known volume of water from the original aquarium and the drug is added to the necessary concentration. Dips are generally considered less than 15 minutes, with baths being longer exposures. The length of exposure should be based on the time required to reach chemotherapeutic levels, but is more often based on the fish's ability to tolerate the treatment.[6] Short-duration dips of one second to one minute are considered purely topical administrations.

Direct topical administration

Localized application of antiseptics, antibiotic, steroids, or dressings can be very beneficial. The most common use of this application is to cauterize or disinfect a lesion by "painting" with a cotton swab. The fish should then be rinsed in a water. Severe tissue necrosis and burns can be caused by leaving the topical treatment in place too long.[6]

Summary

Symptoms and signs of infectious diseases in fish should be followed using the same rules known for history-taking and diagnostic evaluation in any species. Poor water quality is the major cause of fish disease and mortality and should be considered when evaluating any aquarium problem. Well conditioned fish in good, clean oxygenated and temperature regulated water are generally resistant to disease. Veterinarians and their staff are in a position to provide client education services, increase awareness of common fish diseases, and how to avoid fish diseases. It is easier to keep healthy fish than to treat sick fish.

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